Damages and Costs of Stormwater Runoff in the Puget Sound Region

Summary Report

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Table of Contents

List of Figures

List of Tables

I. Executive Summary

The Puget Sound region, with its rapid population growth and urbanization, is in growing need of stormwater management. The region is currently burdened by the large costs of damages and mitigation incurred by increasing volumes of urban runoff and its contaminants.

Stormwater runoff has caused greater flooding, landsliding, and property damage; a decline in drinking-water and surface-water quality; habitat degradation; and contamination of shellfish growing areas. Managing stormwater runoff within the Puget Sound region is not a novel problem—jurisdictions within the region have struggled with this for decades, and they will likely face even greater challenges in the future. Thus, understanding the range of costs inflicted by stormwater and the benefits of effective management is critical to the health of the region.

This report describes the costs of stormwater damage within the Puget Sound region, documents the costs of stormwater mitigation, and presents some of economic benefits of stormwater management.

Summary of stormwater economic costs and impacts:

Major impacts that could be quantified in economic terms are presented below.

Table 1. Stormwater Costs by Impact

Types of Costs	Reported Costs
Flooding, Landsliding, and Property Damage	
Property damage and financial losses	Flood insurance claim payments to the Puget Sound region have totaled $56 million since 1978. Although significant, it still underestimates the total flood losses borne by property owners.
Expense of stormwater facilities	Capital improvement plans of Puget Sound jurisdictions reviewed in this study indicated annual expenditures of $115,333 to $5 million; however, many millions of dollars in shortfalls exist across the Puget Sound region beyond this reported value.
Expense of stormwater programs	Annual stormwater program budgets within the Puget Sound region range from hundreds of thousands to millions of dollars, with typical annual costs of approximately $100/person within a stormwater utility district.
Degradation of Water Quality	
Clean-up of polluted water resources	A review of expenditures within the Puget Sound region revealed that water-quality improvement in a single watershed due to a single stormwater-related contaminant can cost as much as $1.5 million.
Protecting water resources from additional contamination	Various Puget Sound jurisdictions report treatment costs for stormwater discharges ranging from $172,000 to $6.8 million.

Types of Costs	Reported Costs
Loss of Fish and Wildlife Habitat	
Habitat restoration and protection efforts	Individual restoration projects associated with stormwater discharges have cost individual Puget Sound jurisdictions $100,000 to as much as $100 million. Efforts in one jurisdiction to restore and prevent continued degradation of critical fish and wildlife habitat cost $25.8 million in 2005 alone.
Closure of Shellfish Growing Areas	
Shellfish harvest area protection and clean-up	Pollution-prevention and clean-up measures cost $160,000 to $200,000 annually for Drayton Harbor, for example, which was once a valuable Puget Sound shellfish harvest area.
Lost revenues and lost jobs	One Puget Sound harvest area alone experienced a loss of over $3 million in shellfish sales due to closed shellfish harvest areas.
Lost recreation opportunities	The state generated $16.9 million in sales for fishing and shellfishing licenses with over 700,000 customers indicating the popularity of fishing and shellfishing. With the majority of shellfish harvest areas located in the Puget Sound, closed beaches in the region result in lost opportunities for recreational revenue and shellfishing.

In addition to the reported costs listed above, there are consequences of stormwater runoff that are not easily quantified but are also important to recognize. These costs include social, cultural, and quality-of-life changes; lost recreational opportunities due to degraded water quality; reductions in consumer confidence; decreased tourism; and loss of fish and wildlife. Although jurisdictions are currently spending thousands to millions of dollars annually on stormwater management, their expenditures are still dwarfed by the damage being caused by stormwater runoff.

By examining the documented expenditures of stormwater programs, economic costs of stormwater impacts, and some of the unquantifiable losses, decision-makers and stormwater managers can gain a more comprehensive picture of stormwater impacts. Through this larger awareness, they may also develop more cost-effective and justifiable methods to mitigate the effects of stormwater for the protection and improvement of the Puget Sound.

II. Introduction

The biological health of Puget Sound is declining, and much of that decline is a direct or indirect consequence of stormwater runoff (PSAT 2004). As urbanization increases, greater flooding and property damage results from increased volumes of urban runoff, and both upland and downstream water bodies experience degradation of water quality,

destruction of freshwater and estuarine habitat, and harvest restrictions in shellfish-growing areas. This degradation carries a variety of environmental, economic, and social costs that all ultimately arise from the effects of stormwater runoff.

Where quantifiable, these costs can be organized by type of stormwater "impact." In the Puget Sound region these impacts include flooding, landsliding, and property damage; degradation of water quality; freshwater and estuarine habitat damage; and closures of shellfish growing areas. Documenting costs can begin to quantify some of the value of their avoidance through continued and improved stormwater management.

For each of these impacts, distinct categories of stormwater-related "costs" are recognized in this analysis. These categories are direct damage caused by stormwater, cost of government and/or private actions and programs to reduce the effects of stormwater, indirect damage caused by stormwater, and unquantified (or nonquantifiable) costs caused by stormwater. This report presents examples of economic costs associated with the first two categories. The last two categories, namely indirect damages caused by stormwater and unquanitified costs caused by stormwater, are extremely difficult to quantify in economic terms and therefore are acknowledged in a separate section.

While not a comprehensive survey of all costs and benefits, this report does demonstrate some of the losses that the region currently endures. These losses may be financial, or they may be expressed by natural resources such as shellfish harvest areas, fisheries, beaches, and water supplies that have become degraded or lost altogether. Ideally, this information can be used to develop a rational framework in which to determine the best and most cost-effective future expenditures to protect and improve Puget Sound.

An overview of stormwater conditions and effects

Stormwater runoff from urban areas is a well-known cause of physical, chemical, and biological degradation. Most of this degradation is due to the modification of the land surface (Figure 1). The primary consequences of stormwater runoff and urbanization in the Pacific Northwest are:

- **Dramatically changed patterns of flows in downstream channels**: Land conversions and impervious surfaces cause greater peak discharges by factors of 2 to 5, and longer flow durations by factors of 5 to 10. Land conversions and impervious surfaces also dramatically increase the frequency of sediment-transporting and habitat-disturbing flows that move down a channel network by factors of 10 or more (Booth and Jackson 1997).
- **Degradation of in-stream ecology due to increased sediment and pollutant loading:** In-stream biota are extremely sensitive to sediment and pollutant loading. Fish and other aquatic life depend on a particular combination of water and sediment fluxes, and therefore are sensitive to changes in sediment type, size, and loading. Pollutant loading not only cause health effects in stream biota but also can travel up the food chain, causing human health effects and decreased food supplies for endangered species such as Orca whales.

- **Increased stream erosion and degradation of in-stream biological health due to loss of streamside vegetation:** Streamside vegetation helps dissipate flow energy and helps protect the bed and banks from erosion (Booth and others 1997). Vegetation also provides shade to control water temperature and supplies leaf litter that is essential to the health of in-stream biology.

Although the causes and consequences of stormwater damage have long been recognized, solutions have proven elusive. In response to urban-induced runoff changes, jurisdictions have long required some degree of stormwater mitigation. The most common approach has been to reduce flows using detention ponds, which are intended to capture and detain stormwater runoff from developed areas. However, fundamental flaws of detention ponds, such as loss of groundwater recharge and continued alteration of natural flow patterns, are unlikely to ever provide full mitigation for urban runoff (Booth et al. 2002).

Local stormwater programs to reduce pollution have also not kept pace with increased urban development. For example, National Pollutant Discharge Elimination System (NPDES) permits issued by the state Department of Ecology have required the largest jurisdictions in the Puget Sound region to implement stormwater treatment programs for several years. The most recent NPDES permits now require most cities and counties to implement similar treatment programs.

However, less populous and more rural jurisdictions often have less developed stormwater management programs. Existing, older storm systems are also problematic, because they often provide little, if any, treatment; their locations are often unknown; and they are often difficult to access. The challenges to improve stormwater management are substantial, but the consequences of not managing these impacts turn out to be even more costly.

III. Economic Costs of Stormwater

The consequences of stormwater runoff are as diverse as the watersheds that are affected. For simplicity, available costs were organized by the following impacts: flooding and property damage, degradation of water quality, destruction of freshwater and estuarine habitat, and closure of shellfish growing areas. The costs under these impacts include direct damage, mitigation efforts, and private and governmental programs. Given the existing information, other indirect and broader non-quantifiable costs could not be quantified in economic terms; therefore, they are presented in a separate section.

A. Flooding, landsliding, and property damage

The direct impact of stormwater on property is perhaps the most prominent, overt expression of the "cost" of urban runoff. Damage and financial losses, the expense of stormwater facilities, and the cost of complying and administering regulatory programs designed to reduce these problems are all apparent.

Direct damage to property

Extensive property damage occurs during periods of heavy rain that result in flooding and landslides (e.g., Figure 2). Flooding and landslides are natural occurrences, but they are particularly common in areas of urban development and are exacerbated by insufficient or poorly maintained stormwater and drainage facilities.

Most city and county officials that were interviewed report that flooding and drainage problems are the most common concerns from citizens because they result in direct damage to their property and surrounding community. Anecdotal information clearly demonstrates the general magnitude of damage from urban flooding, but precise costs are difficult to assign to stormwater runoff alone. For example, the total amount of flood insurance claim payments made in the Puget Sound region by the National Flood Insurance Program has totaled $56 million since 1978 (BureauNet 2006). Although a significant amount by itself, it does not include all flood losses borne by the property owners themselves due disparities in insurance coverage.

Property damage also results from landslides. A study of landslides within the Seattle area showed that 84% of landslides were influenced by some type of human activity, including drainage and stormwater issues (Shannon & Wilson 2001). The City of Seattle is projected to spend an average annual amount of $3.78 million (in 2006 dollars) from 2005–2010 on landslide mitigation (SPU and others 2004).

Cost of stormwater facilities and stormwater management programs

In addition to the direct property damage caused by flooding, agencies endeavor to respond both by constructing damage-reducing capital facilities and by implementing broader stormwater management programs.

In the Puget Sound basin, the annual budget of individual stormwater and flood management programs can be on the order of hundreds of thousands to millions of dollars, depending on size and population of the area. The largest jurisdictions (namely, cities and counties covered under NPDES Phase 1 permits) in Washington State reported expenditures of $147.6 million (A. Wessel, pers. commun. June 13, 2006), of which 91% of the costs were from Puget Sound jurisdictions. These tabulated costs, although substantial, may be underestimated, because NPDES Phase 1 permitees are only required to report expenditures needed to meet the 1995 permit. When stormwater management costs are expressed per capita, typical management costs are on the order of $100/person/year, exclusive of the episodic damage that is also incurred.

Specific examples demonstrate the degree to which individual jurisdictions are already experiencing substantial management costs, and the magnitude of their estimated shortfalls. The City of Bellingham has estimated $300,000–500,000/year in additional funds would be required to keep up with current technologies and population growth beyond the $4.8 million currently budgeted (W. Reilly, pers. commun. February 6, 2006). On a larger scale, Snohomish County identified 220 recommended projects with a total project cost of $85 million (representing a per capita expense of about $130) (Snohomish

County 2005). As of 2005, the county has 163 projects remaining uncompleted at an estimated cost of $69 million.

Larger jurisdictions have been successful in reducing property damage due to flooding by taking preventive measures, such as restricting new development in flood-prone areas or requiring stricter regulations when building in floodplains. However, they only reduce the further growth of such problems since frequent complaints and ongoing problems are present in areas of older development.

B. Degradation of water quality

Representatives from most jurisdictions interviewed identified water quality as the main problem resulting from stormwater runoff in their area. However, many interviewees felt that water-quality issues are often ignored because local officials and citizens are more immediately concerned about flooding and drainage issues.

The costs identified in this study that are directly associated with degraded water bodies are primarily those associated with cleaning polluted surface water bodies and protecting such resources from future or additional contamination. Reported expenditures for the clean-up of polluted water and protection from additional contamination in the Puget Sound range from $172,000 to $6.8 million.

Degradation of drinking-water supplies

Although Puget Sound is the ultimate recipient of polluted water, the consequences of degraded water quality begin in upstream water bodies and drinking-water supplies. Threats to their quality can create an immediate public health risk and necessitate significant financial outlays.

For example, Lake Whatcom is an important drinking-water supply that supplies water for approximately 86,000 residents in the northeast part of the Puget Sound region (Cusimano and others 2002). By allowing development around the lake, Whatcom County and the City of Bellingham now must retrofit stormwater outfalls to treat stormwater discharge entering the lake. Whatcom County is spending about $800,000 in 2006 alone to construct water-quality treatment retrofits, such as swales and vaults, to mitigate stormwater effects on Lake Whatcom (K. Christensen, pers. commun. June 12, 2006).

A lesson in deferred costs can be found in history of the water-supply system for the 9 million people in New York City. Increased development within these watersheds threatened this water supply with contamination from onsite septic systems and stormwater runoff. New York had two choices: either build a water filtration system or protect its watersheds from sources of contamination (NRC 2005). The estimated cost of building and maintaining a new filtration system necessary to meet drinking water quality standards was $6 to $8 billion, compared to a projected cost of $1 to $1.5 billion to protect and restore natural ecosystem processes in the watershed. New York City opted to protect the watersheds to maintain water quality. This strategy saved the region's tax payers many billions of dollars and also avoided the cost of maintaining and operating the

treatment system. The largest water purveyors in the Puget Sound region (the cities of Seattle, Tacoma, and Everett) are pursuing a similar strategy of source protection.

Degradation of surface water quality

Even where drinking-water supplies are not directly affected, degradation of the water quality of streams and rivers is a primary concern of stormwater managers and public works directors. The Department of Ecology (DOE) notes that "water quality standards are frequently exceeded in urban stormwater runoff. Where that runoff makes up the bulk of the flow in a lowland stream, violations are highly likely" (E. O'Brien, DOE, pers. commun. May 31, 2006).

Elevated temperature and fecal coliform bacteria are the two most common water-quality problems reflected in 303(d)-listed impaired water bodies across Washington State (Erickson 2004). Runoff from urbanized areas will always cause violations of fecal coliform standards (and consequently result in shellfish bed closures), according to DOE.

Local examples of direct water quality costs are abundant, given the tremendous efforts being made to improve the water quality in the Puget Sound basin. A particularly costly example of fecal coliform contamination, in addition to temperature and dissolved oxygen issues, is provided by Thornton Creek, located in the City of Seattle (DOE 2005). Thornton Creek is Seattle's largest creek and home to chinook, coho, and sockeye salmon, as well as cutthroat and rainbow trout (Seattle Public Utilities and others 2004). To improve water quality, Seattle Public Utilities (SPU) is installing stormwater treatment practices for a 670-acre urban subbasin. For 2006, the DOE Centennial Clean Water Program, that provides financial assistance for water quality projects, gave the City of Seattle $6.8 million for this project (DOE 2005a). The program also offered SPU $1 million in funding for ultra-violet light disinfection in three Seattle creeks (Thornton, Pipers, and Longfellow creeks) to reduce fecal coliform levels.

C. Freshwater and estuarine habitat damage

Direct costs of habitat damage are difficult to assign, because the "value" of habitat is rarely measured in strictly economic terms. More commonly, the damage is reflected in the response of the organisms that depend on that habitat (e.g., "loss of fish"), but the specific contribution of habitat loss to that change is difficult to estimate. Quantifying economic costs for this report, therefore, focused on remedial costs rather than the economic "value" of the lost resource. Such remedial costs range from $100,000 to over $100 million across Puget Sound, although they are surely reversing only a scant fraction of the actual damage that had occurred. Despite this limitation, the amount of money being spent is substantial.

Loss of fish and wildlife habitat

In general, the habitat values of urban streams and creeks within the Puget Sound region are significantly degraded. Problems identified by various jurisdictions around Puget Sound include channel incision, sediment contamination, bank erosion, sediment

loading, and resulting loss of salmon runs and overall degradation of aquatic health. Although some jurisdictions do not have the funds or staff to document habitat degradation, such damage is ubiquitous with urban development and is almost certainly occurring throughout western Washington.

The clean-up of Commencement Bay provides a particularly challenging and costly example. This Superfund site suffers from highly contaminated sediments, extreme habitat destruction, water pollution, and ecological losses. Sediment dredging is anticipated to be completed by the end of 2006 at an estimated final cost of over $100 million and stormwater has been identified as a significant source of the contamination (City of Tacoma 2006; S. Hansen, pers. commun. July 28, 2006).

Current steps are being taken by the city to mitigate stormwater contamination in the Thea Foss Watershed Basin. In 2005 alone, these efforts to clean up sediments and provide stormwater source controls to prevent recontamination cost the city $26 million (City of Tacoma 2006). Based on 2001–2005 stormwater monitoring completed by the City of Tacoma, stormwater contaminant loads were reduced by 40–80 percent since the late 1990s (City of Tacoma 2006a).

By one estimate (Bernhardt et al. 2005), $1 billion per year is currently being spent nationwide to restore streams and rivers, and a significant fraction of that outlay is contributed by the Pacific Northwest in general and the Puget Sound region in particular. An even greater cost, however, is the intangible (and likely irrevocable) loss of biological resources and diversity.

D. Closure of shellfish growing areas

Determining the cost of shellfish-area closures and assigning a reasonable contribution to urban runoff are challenging because the shellfish industry has significant and multifaceted value, both economic and social, and because Puget Sound is a water body that is contaminated by multiple sources from urban and non-urban areas alike. Quantifiable costs include protective measures and the direct loss of revenue. The role of urban runoff can be determined only by inference, with the assumption that the proximity of shellfish beds and urban areas reflects a probable linkage between them.

Extent of the problem

According to the Washington State Department of Health, many counties and jurisdictions have been historically successful in minimizing the effects of pollution on their shellfish harvest areas (pers. commun. Bob Woolrich, 2006). Yet many of these same areas are now being pressured by rapid growth along their shorelines and development of the contributing watersheds. At least four recent shellfish growing area closures in the Puget Sound are adjacent to urban areas and are almost certainly a result of urban stormwater runoff. The closures include Henderson Inlet, North Dyes Inlet, North Bay, and Lynch Cove. More telling, there are simply no remaining open shellfish areas anywhere along the highly urbanized east coast of Puget Sound, from Tacoma to Everett (B. Woolrich, pers. commun. June 12, 2006).

Protective Measures

Cities and counties where shellfish beds are degraded to a lower classification must develop closure response plans and designate shellfish protection districts. Closure response plans cost local governments money to develop and implement. Thurston County formed a shellfish protection district for Henderson Inlet. While the county is still in the process of implementing stormwater mitigation plans, the City of Lacey has already taken steps to minimize their stormwater impacts on Henderson Inlet. Currently, the city is spending $1.6 million on the College Ditch Stormwater Facility to treat storm and sewer discharges entering Woodland Creek, which is a tributary to Henderson Inlet (D. Christenson, pers. commun. June 8, 2006). Other stormwater retrofits are also being installed throughout Lacey.

In some areas, local funds are being invested specifically for stormwater management techniques to protect shellfish harvest areas. For example, 14% of the total stormwater program costs in Kitsap County fund the health district to minimize stormwater impacts. In contrast, many other jurisdictions in the Puget Sound region are not properly funded or staffed to fix many of the stormwater problems, or even to identify the pollution source.

Lost revenues and lost jobs

Shellfish production within the state of Washington accounts for 83% of the total shellfish production by weight on the West Coast of the United States (Pacific Coast Shellfish Growers Association 2004), and many of the harvest areas within the state are located in the Puget Sound basin. When a shellfish harvest area is closed, the losses suffered by shellfish growers can be dramatic (Figure 4).

An example of the impact that shellfish closures have on commercial shellfish industry can be found in Drayton Harbor (Whatcom County). Once a well-known area for commercial oyster and recreational shellfish harvesting, rapid development of the watershed resulted in a total ban on shellfish harvesting in the entire harbor starting in 1999 (Callahan and Menzies 2004) with closures beginning as early as 1995. Stormwater runoff is one of the top three significant sources of contamination to Drayton Harbor. Substantial efforts by non-profit organizations and local governments have been made to clean up the harbor at an estimated cost of $160,000–200,000 annually (G. Menzies, pers. commun. June 15, 2006).

The closure of shellfish harvesting areas has also impacted the Drayton Harbor community and the Lummi Nation. Prior to the 1995 closure, the Lummi Nation harvested about 30,000 lbs of clams per year, which thus represents a value of $870,000 in lost revenue over the past 10 years of closures (G. Menzies, pers. commun. June 15, 2006). Lost commercial oyster revenue is estimated at $2.5 million over the past decade. As with other losses of resources, it is important to note that these costs are significantly underestimated since they fail to account for lost recreational, tourism, and business revenues resulting from closures.

Recreation

The value of the recreational shellfishery in Puget Sound is substantial, and so the cost of their recreational shellfish bed closures can be significant. The Washington Department of Fish and Wildlife (WDFW) licensing department reported $16.9 million in state sales for fishing and shellfishing licenses, for a total of 763,109 customers (WDFW 2006). This illustrates the great recreational value that shellfish growing areas have in the Puget Sound. In 2001, the U.S. Fish and Wildlife Service discovered that average recreation expenses per angler were about $1,046 (U.S. FWS 2002), which include licensing, food, lodging, and equipment. Based on the number of 2005 fishing and shellfishing license customers in Washington and estimated expenses per angler, approximate sales revenues of over $900 million (2006 value) could have been generated by Washington State from recreational fishing and shellfishing in 2005 alone.

IV.Other "Costs" of Urban Stormwater

The majority of this report presents examples of incurred costs (i.e. dollars spent) and lost economic value that have resulted from our present levels of urban development and its associated stormwater management. However, other commonly articulated "costs" were identified that do not translate readily into economic terms, or that cannot be assigned unequivocally and solely to urban runoff. They are addressed in this section. The most prominent of these losses is the local collapse of aquatic ecosystems, but degradation is also expressed by the reduced recreational value of polluted waters and the lost opportunity cost of those damages that cannot be reversed. This, in turn, results in not only the quantified costs outlined previously but also less tangible reductions in consumer confidence, tourism, and the region's quality of life.

Loss of fish

Urban stormwater is a critical element in the decline in urban salmon populations but it is not the sole cause, because the cumulative effect of the wide variety of human activities in urban basins profoundly influences urban streams and their biota (Booth et al. 2004). The effects of individual stormwater pollutants on fish species have been studied in the Puget Sound region, but even the strong causal (and detrimental) linkages that can be documented do not easily translate into discrete "costs." The following are just some of the unquantifiable consequences of stormwater runoff on fish species:

1. High death rates of pre-spawning salmon have been discovered in Puget Sound lowland streams since the 1990's. It is estimated that 20–90% of spawning coho salmon in the fall have been affected, notably in Seattle's Longfellow Creek, with stormwater runoff the as-yet unconfirmed but most probable source (NOAA 2006).
2. Coho salmon suffer from increased lethargy and decreased feeding and swimming rates when exposed to Chlorpyrifos (Sandahl et al. 2005), a common insecticide found in surface waters of the Puget Sound basin (Bortleson and Ebbert 2000). A study of streams in King County detected

pesticides, including Chlorpyrifos, more frequently and at higher concentrations during storm events than at normal base flow (Frans 2004).

3. Coho salmon are affected by copper exposure, a common constituent of stormwater runoff, which inhibits their olfactory system that is vital for the salmon to recognize predators and kin (Baldwin et al. 2003).
4. The risks of English sole developing liver lesions increase with exposure to polycyclic aromatic hydrocarbons (PAHs), especially in urban areas where sediment PAH concentrations are the highest (Puget Sound Water Quality Action Team, 2002). Stormwater is suspected to be a significant source of PAH contamination at these sites.

Although damages such as these do not have a direct dollar value attached to them, they must be part of any evaluation of the consequences of urban development in the Puget Sound region because their effects are so widespread.

V. Conclusion

The economic costs of stormwater in the Puget Sound region range from thousands to millions of dollars per year within a single jurisdiction; per capita costs are tens to hundreds of dollars for each program element that include flooding and drainage, landslide mitigation, water quality, and habitat. In aggregate, current expenditures and unfulfilled needs almost certainly exceed $1 billion for the region over the next decade. These costs include losses from degraded water quality, habitat and restoration, landslide mitigation, and drainage and flood mitigation. Figure 5 highlights some examples of the division of costs associated with managing stormwater and mitigating stormwater-related problems.

Efforts to reduce flooding and drainage are the largest costs among all jurisdictions, regardless of size. In contrast, the importance of water-quality and habitat issues varied significantly among the jurisdictions interviewed, with funding to address these problems also varying greatly. Each of these problems, however, has a significant contribution from stormwater runoff, and so the magnitude of these costs are a good first-order estimate of what the region is spending, and how it is spending it, on measures to reduce stormwater-related damage.

Documented expenditures in the name of urban stormwater management are substantial but the hidden costs of untreated problems may be even greater. Every category of cost discussed in this report—direct damage, stormwater facilities and programmatic responses, and unquantifiable (but very real) losses—must be acknowledged as the region seeks to develop a rational framework for deciding the best and most cost-effective path to protect and improve Puget Sound.

VI.Figures

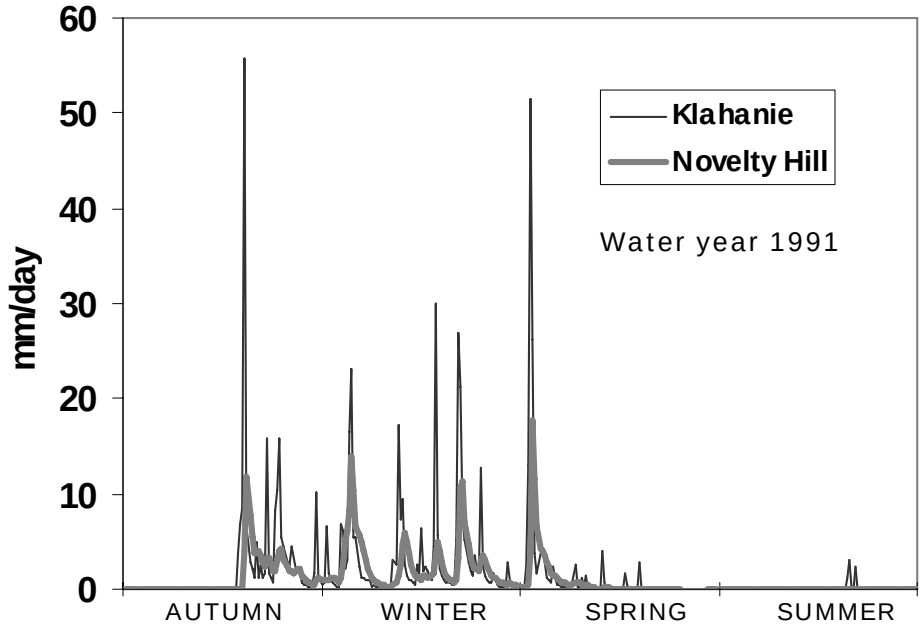

Figure 1. One year's gauged discharges for two contrasting watersheds in east-central King County, displaying the changes in streamflow that result from forested ("Novelty Hill") to suburban ("Klahanie") land conversion. The Novelty Hill catchment was covered in mature second-growth forest when these data were recorded, and it shows the typical low-development pattern of sporadic wintertime peak discharges, moderate intervening base flows, and low (or absent) discharge between mid-spring and early autumn. The Klahanie catchment displays dramatic increases in stormflows year-round (data from Burges et al. 1998).

Figure 2. Flooding at Old Belfair Highway near Gorst in Kitsap County. Photo courtesy of Dave Dickson, Public Works assistant director of Kitsap County, WA.

Figure 3. Twin eight-foot diameter outfalls that discharge stormwater into the Thea Foss Water Way (Source: City of Tacoma 2006).

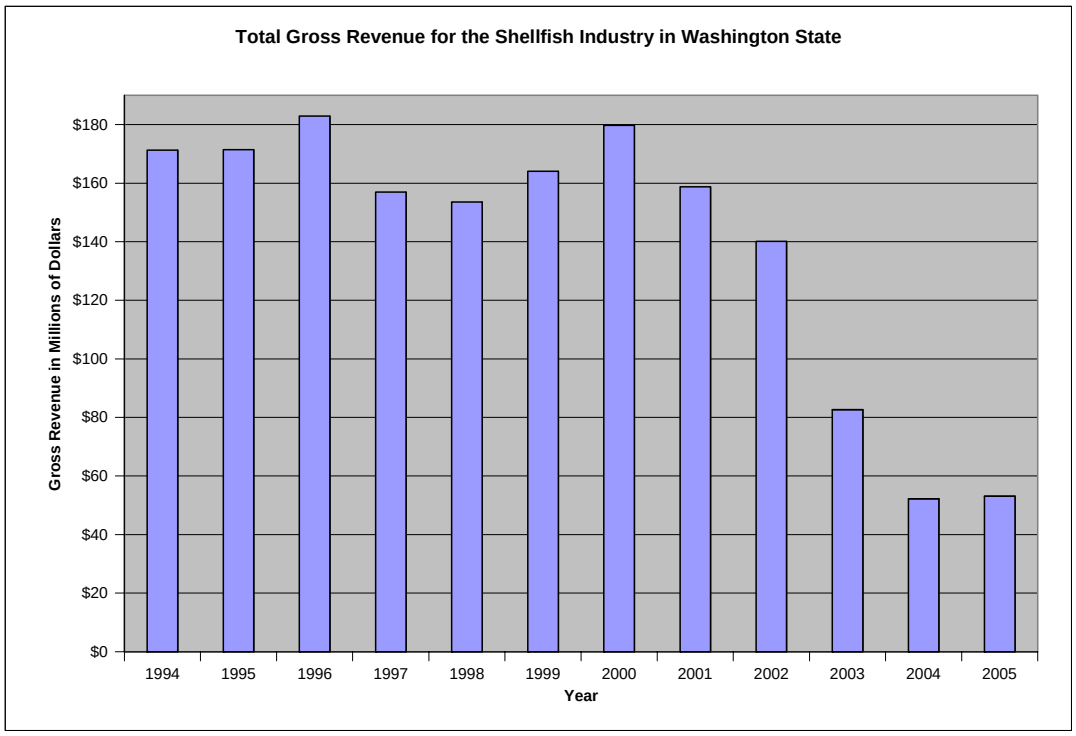

Figure 4. Total Gross Revenue for the Shellfish Industry in Washington State (Washington State Department of Revenue 2006)

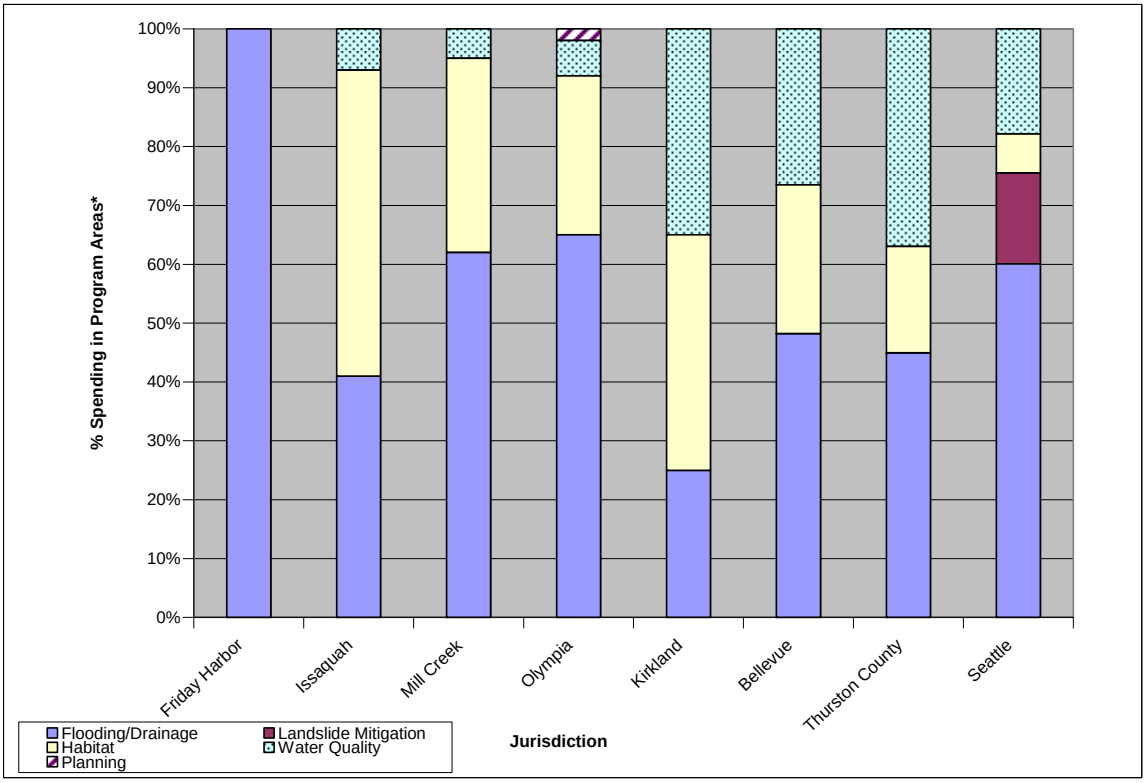

Figure 5. The division of capital improvement project costs within various stormwater programs in the Puget Sound region, in order of increasing population. The total capital improvement project costs are as follows (2006 dollar values): (a) Town of Friday Harbor costs represent a total budget of $2,422,000 for years 2006-2027 (Gray & Osborne 2005), (b) City of Issaquah total budget = $7.3 million for years 2005-2010 (City of Issaquah 2005), (c) City of Mill Creek total budget = $5.3 million for years 2005–2011 (City of Mill Creek 2005), (d) City of Olympia total budget = $12.5 million for the capital improvement program from 2004-2012 (City of Olympia 2003), (e) City of Kirkland total budget = $8.7 million for years 2004–2009 (City of Kirkland 2005), (f) City of Bellevue total budget = $30 million for projects from years 2005–2011 (City of Bellevue 2005), (g) Thurston County total budget = $5.7 million for years 2006–2011 (Thurston County 2005), and (h) City of Seattle total budget = $19.0 million as an average annual cost for years 2005–2010 (Seattle Public Utilities and others 2004). It is important to note that the impacts due to stormwater may not necessarily be reflected in stormwater and surface water program expenditures displayed above, because stormwater costs may also be shared with other departments.

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VIII. Appendix A

Sources of Information

Name	Organization
Mike Milne	Brown and Caldwell Environmental Engineers & Consultants
Katrina Landau	Citizen's for a Health Bay
William Reilly	City of Bellingham, Public Works Department
Kerry Ritland	City of Issaquah
Doug Christenson	City of Lacey, Stormwater Manager
Andy Haub	City of Olympia Public Works
Christy Strand	City of Tacoma Public Works Department
Shauna Hansen	City of Tacoma, Public Works Department
Geoff Menzies	Drayton Harbor Shellfish Protection District Advisory Committee Chairman, Manager of the Drayton Harbor Community Oyster Farm
Douglas Kelly	Island County Groundwater Resources Program
Steve Bleifuhs	King County, Department of Natural Resources and Parks
Steve Foley	King County, Department of Natural Resources and Parks
Shaun Ultican	Kitsap County Health District
Dave Dickson	Kitsap County, Public Works Department
Kathryn Liberman	Muckleshoot Tribe
Sarah McCarthy	NOAA Northwest Fisheries Science Center
Fran Wilshusen	Northwest Fisheries Commission
Heather Trim	People for Puget Sound
Mary Van Haren	Pierce County
Hans Hunger	Pierce County Public Works & Utilities
Stuart Glasoe	Puget Sound Action Team
Sue Joerger	Puget Soundkeeper Alliance
Tracy Tackett	Seattle Public Utilities
Dick Oltman	Shelton Skookum Rotary Club Foundation
Craig Young	Snohomish County Watershed Steward
Bill Dewey	Taylor Shellfish Company
Irene Fadden	Taylor Shellfish Farms
Scott Clark	Thurston County
Sue Davis	Thurston County Health Department
Mark Swartout	Thurston County Natural Resources Program
Arthur Lee	Tulalip Tribe, Community Development
Misha Vakoc	U.S. EPA Region 10

Name	Organization
Sandra O'Neill	Washington Department of Fish and Wildlife
Camille Speck	Washington Department of Fish and Wildlife, Point Whitney Lab
Teri King	Washington Sea Grant Program
Anne Dettelbach	Washington State Department of Ecology
Bill Moore	Washington State Department of Ecology
Margaret Dutch	Washington State Department of Ecology
Ralph Svrjcek	Washington State Department of Ecology
William Hashim	Washington State Department of Ecology
Jessica Archer	Washington State Department of Ecology, BEACH Program
Brian Lynn	Washington State Department of Ecology, Shorelines & Environmental Assistance Program
Melissa Gildersleeve	Washington State Department of Ecology, TMDL Program
Ann Wessel	Washington State Department of Ecology, Water Quality Program
Bob Woolrich	Washington State Department of Health, Shellfish Program
Kurt Baumgarten	Whatcom County, Planning Division
Kirk Christensen	Whatcom County, Public Works Stormwater Division